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Sustainable Biofuels from Forests: Meeting the Challenge

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Biofuels, generally defined as liquid fuels derived from biological materials, can be made from plants, vegetable oils, forest products, or waste materials. The raw materials can be grown specifically for fuel purposes, or can be the residues or wastes of existing supply and consumption chains, such as agricultural residues or municipal garbage. In this series of reports, sponsored by the Energy Foundation, we explore the production and use of biofuels from an ecological perspective. Each report addresses one aspect of biofuel production. The report topics are biodiversity and land use; forestry; grasslands, rangelands, and agricultural systems; and biogeochemistry. A capstone issue will present a synthesis of the ecological dimensions of biofuel production.

These reports, which were reviewed by an Advisory Committee, are based upon scientific manuscripts initially presented at a conference in Washington, DC, on March 10, 2008 (see www.esa.org/biofuels). The conference was hosted by the Ecological Society of America (ESA) and sponsored by a consortium of other scientific organizations, nongovernmental organizations, federal agencies, and the private sector. ESA also issued an official statement on the topic in January 2008, which can be found at:

http://www.esa.org/pao/policyStatements/Statements/biofuel.php

As innovations are made in the production and use of biofuels, ecologists worldwide will continue to actively monitor their impacts.

Cover photo credits: *John Deere slash bundler in operation in eastern Finland feeding slash (Left) into the bundler and depositing wrapped bundles (Right) for transport to a local forest bioenergy power plant*
Inset: Finland's dedication to diverse bioenergy fuels. Photos by D.G. Neary.

Sustainable Biofuels from Forests: Meeting the Challenge

Marilyn A. Buford and Daniel G. Neary

For thousands of years, people have cut down trees to burn for heat and to cook their food. With the advent of the industrial revolution, wood was even used to fire the combustion engines that powered some of the earliest trains and steamboats. Today energy experts are considering the use of wood-based bioproducts to displace fossil fuels, but what they envision is something much more complex and much more efficient than simply logging trees and burning them in power plants.

In this report, we examine how forest products could be used to create bioenergy, and define the wide array of wood-based products that could be used for fuel. We also present current statistics on the availability of those forest products. We explore how some European countries balance the need for fuel against other demands placed on their own forestlands, and review some of the forest practices and certification programs which have proven successful and sustainable in other regions of the world.

What Can Forests Provide?

When scientists discuss using forest products for energy, they often refer to woody biomass. This phrase can include any part of the tree, including the bole wood, the limbs, the tops, the roots and even the foliage, and thus can refer to both commercial and non-commercial parts of trees.

Woody biomass may include trees that have been damaged or killed by drought, disease, or fire. It may also include the wood which is removed when forests are treated with prescriptive silvicultural treatments. Such treatments might be made, for example, in an area where disease or insect damage has been discovered, or tree densities need to be reduced to promote healthy growth. Research is also being conducted on the use of "purpose-grown" wood such as plantation forests for the specific production of biofuels.

Paper and wood products that are recovered both before and after consumer use and which are not suitable for recycling, however, could also be sources of woody biomass and could be used for the production of energy. The same is true for wood construction debris or urban tree trimmings, and the wood recovered from salvage operations could also be a source of woody biomass for energy production.

Woody biomass is one of the only renewable materials that can be used to produce power, heat, and liquid fuels at the same time. Although biomass is used in the production of US electricity, the use of waste materials is still a relatively new option in wide scale production.

How is Energy Produced from Woody Biomass?

Woody biomass can be converted to biofuels, biobased products, and biopower through various means including biochemical, thermochemical, and direct combustion pathways. Material handling and initial processing varies by composition and form. For example, depending on the desired set of biofuel products, preprocessing of wood chips differs somewhat from that of recycled paper.

In biochemical conversion, woody biomass is broken down to sugars using either enzymatic or chemical processes and then converted to ethanol or other products via fermentation. Lignocellulose (mainly lignin, cellulose and hemicellulose) is the primary component of woody biomass. Biochemical conversion breaks down cell walls through the introduction of enzymes or acid in order to extract the sugars which are then converted to biofuels using microorganisms for fermentation [see www1.eere.energy.gov/biomass/biochemical_conversion.html].

Thermochemical conversion uses heat and pressure-based processes to convert woody biomass to alcohols and hydrocarbon fuels, chemicals, and power. In gasification conversion, woody biomass is broken down using heat to produce synthesis gas, also called syngas. The type of biomass and the content of the syngas vary by initial biomass, moisture content, type of gasifying equipment, and agents as well as the temperature and pressure used in the process. In pyrolysis processing, woody biomass is broken down using heat in the absence of oxygen, creating a bio-oil that can be refined to hydrocarbon products. The decomposition occurs at lower temperatures than gasification processes, and produces liquid oil rather than gas. The resulting oil varies by the type of biomass used [see www1.eere.energy.gov/biomass/thermochemical_conversion.html].

In some industries, the spent steam from the power plant is also used for manufacturing or to heat buildings. These systems are known as Combined Heat and Power or CHP systems. Paper mills, for example, often generate electricity and process heat in recovering chemicals from spent pulping liquors. Some facilities also co-fire with biofuel materials. Co-firing occurs when woody biomass is burned with fossil fuels (such as coal) in conventional power generating facilities [see www.nrel.gov/learning/re_biopower.html].

How Much Energy Can Woody Biomass Supply in the US?

The real value of forest biomass for energy production is its renewability and potential sustainability; woody biomass from forests can be harvested and then grown again in a sustainable manner. This is very different from fossil fuel-based systems which produce energy from coal, oil, and natural gas. What remains in question is how much energy woody biomass could provide in the US.

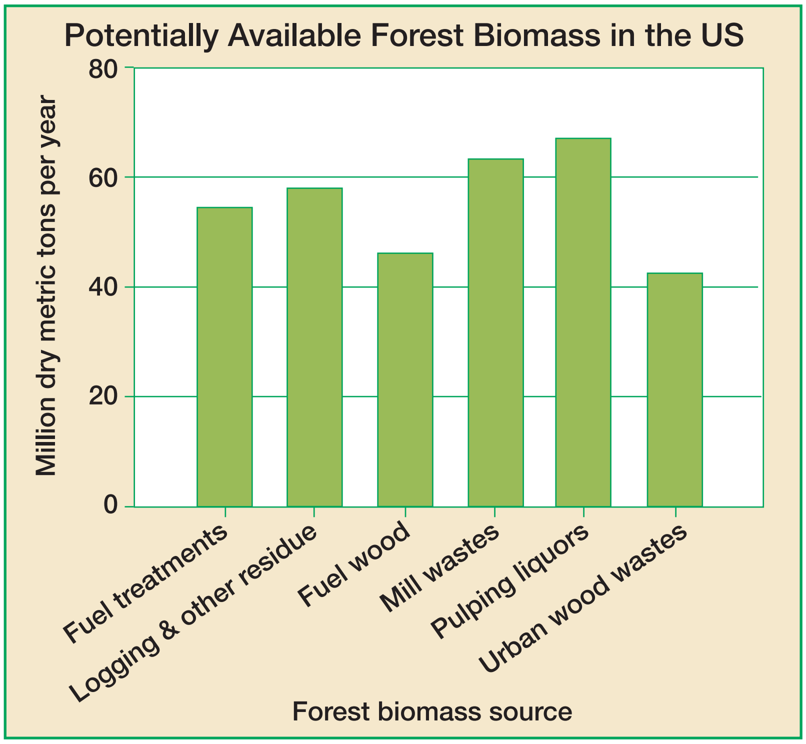

Figure 1. *According to the Billion Ton Report, a potential of 334 million dry metric tons of forest wastes and residues could be produced each year on a sustainable basis in the US.*

In a much-noted study published in 2005, Robert Perlack and others from the US Department of Energy sought to answer a very large question: could the US produce a sustainable supply of biomass which would be sufficient to displace at least 30 percent of the nation's petroleum consumption? Their study, which became known as the Billion Ton Report, concluded that the answer was yes (Perlack *et al.* 2005).

The report examined more than just forest biomass waste and residue. Agricultural crops such as corn and soybeans, agricultural residues, and perennial plants were also considered in their analysis. But woody biomass played a large role in their figures; their calculations showed a conservative estimate of 334 million dry metric tons (368.2 million dry short tons) of forest wastes and residues could be produced each year on a sustainable basis (Fig. 1).

The authors of the Billion Ton Report considered logging residues and other removals from traditional logging activities, as well as silvicultural operations and fuel treatment thinnings on timberland and other forestland. They also included primary and secondary solid wood processing mill wastes, urban wood wastes, fuel wood, and pulp and paper mill waste solids and liquids.

An update to the Billion Ton Report is expected soon. The new analysis is expected to also include potentially available wood from conventional sources and wood which would be grown purposefully for use as energy, such as short rotation hybrid poplar or willow plantations.

Short Rotation Woody Crops: Purpose-Grown Wood for Energy and Bioproducts

Short rotation woody crops (SRWC) culture involves growing trees using both forestry and agronomic practices. These systems are currently capable of producing 8-20 metric tons/hectare annually, with harvests at 3 to 15 year frequencies depending on the species and location. SRWC candidates in the US currently include hybrid poplar, willow, cottonwood, sycamore, sweetgum, loblolly pine, and potentially eucalyptus. There are over 60,000 ha (148,000 acres) of operational SRWC in the US, primarily in the upper midwest and northwest.

In the US, there is active SRWC research which is focused primarily on developing and testing new, faster growing, more resource-efficient and disease-resistant trees; understanding growth and productivity controls; exploring remediation potential; quantifying habitat dynamics; quantifying carbon sequestration potential of these systems; developing ecologically sound harvest and collection systems optimized for SRWC systems; and developing integrated management systems for the production of energy feedstock and other goods and services from SRWC systems.

Who Owns the Current Woody Biomass Resources in the US?

When examining the conclusions of Perlack and his team, it is important to understand what is and is not available in the US forestlands. Almost one third of the nation (about 303 million ha or 748.7 million acres) is covered in forest (Fig. 2). Approximately 31 million ha (76.6 million acres) is set aside for "non-timber uses," such as parks and wilderness, and about two-thirds of the overall forest is classified as productive timberland, or land which is capable of growing more than 1.4 cubic meters/ hectare/year of wood. There are also 68 million ha (168.0 million acres) of forestland which cannot produce enough wood to be considered timberland because of constraining site conditions including poor soils, lack of moisture, high elevation or rockiness.

About 57% of all forestland in the country is privately owned, but not all of that can be considered available for use. To understand what is truly available it can be helpful to consider the numbers in terms of what is considered both productive and not reserved. About 71% of the productive timberland is owned by either private individuals, partnerships or the forest industry. The remainder is either reserved (land which has been withdrawn from timber utilization through statute, administrative regulation or designation without regard to productive status) or not accessible (Fig. 3) (Smith *et al.* 2002).

The Challenge of Sustainability

Forestlands are expected to meet a long list of demands beyond energy production, including the production of water, wood and non-wood products. Humans also rely on these areas for the provisioning of many other services, including recreation, and people value the habitat forests provide to wildlife. There is also a strong need to maintain or enhance the forests' ability to sequester carbon and thus help to mitigate global climate change.

In light of all of these ecosystem services (services to humans provided by ecosystems), many policymakers, land managers, and scientists are seeking ways to sustainably manage these areas so that bioenergy feedstock production is integral to the sustainable production of goods and services from these lands. Sustainability has become a buzz word in modern society, and because of its popularity, the term has taken on many meanings. Generally, sustainability is used to describe the ability to meet current needs in a manner that does not jeopardize the capacity of future generations to have their needs met.

When considering the question of sustainability and

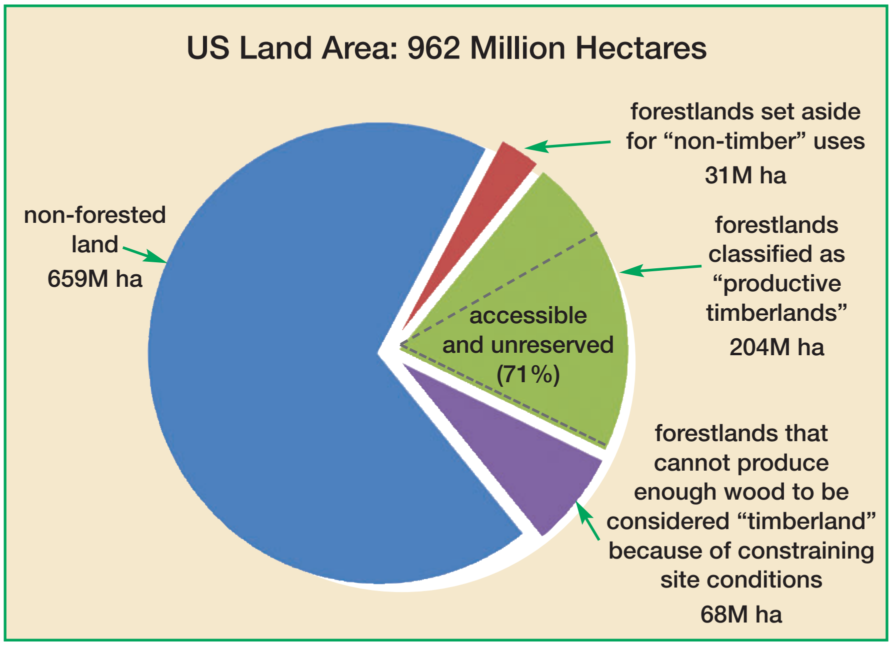

Figure 2. *Classification of US land area.*

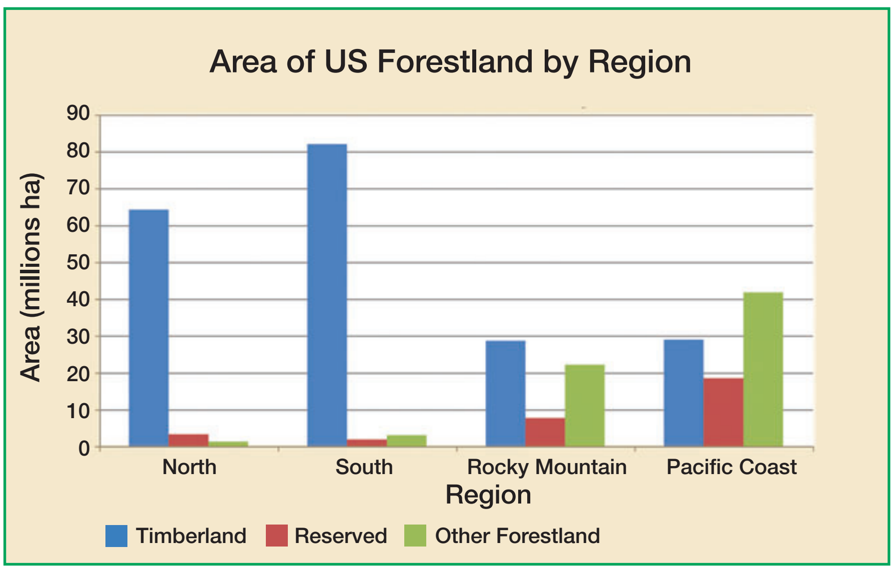

Figure 3. *Distribution and categories of US Forestland.*

biofuels, the Ecological Society of America chose to define the term this way: sustainable production of biofuels must not negatively affect energy flow, nutrient cycles and ecosystem services (ESA 2008). For the purposes of this publication, we will use this definition but will work with the knowledge that a larger concept of sustainability exists and may demand consideration as biofuel use increases.

As the global economy expands and natural resources demands soar, the real challenge may be to enhance and manage the capacity of all ecosystems across the globe to meet our future resource needs without sacrificing sustainability or ecosystem functioning. This will involve merging forestry research on sustaining and restoring ecosystems with research on natural resource products such as wood.

Sustainable development of wood-based fuels must avoid degradation of streams and lakes and avoid conversion of native prairie, forest, wetlands, and associated habitats.

The list of future challenges specifically associated with the sustainable development of wood-based fuels is likely to include:

- resource availability, feedstock sources, feedstock production and management, and other components of supplying wood feedstock;
- harvesting and forest operations technologies, transportation, in-forest pre-processing technologies for feedstock added value;
- types of conversion technologies including their feedstock needs, conversion efficiencies and costs;
- integrated management systems for energy and other goods and services;
- information, data, and decision tools, and finally,
- development and deployment of biomass to energy facilities.

It is evident, then, that the future of US forest management will need to consider and somehow balance the need to provide energy and meet the need for the provisioning of other goods and services. Examinations of biofuel and forestry work which is currently underway in other regions of the world may prove helpful in these efforts.

An Examination of Biofuel Production in the European Union

The extent of forestland in the European Union (EU) varies greatly among countries, ranging from 1% to 74%. Most EU forests are privately owned, although public agencies own and manage significant areas in almost all countries. Some of the EU members from the former Soviet Union have high amounts of public forests, although privatization is increasing there, too.

Surprisingly, the amount of land covered by forests in Europe is increasing, even though some forest areas are lost each year to urbanization. This is mostly due to expansion onto marginal lands, and reforestation of abandoned crop lands. [Further information and discussion on the topic of marginal lands can be found in Dale *et al.* 2010].

Forestland throughout the region is managed for wood production, biodiversity conservation, recreation and soil and water protection. In fact, over 10% of the EU's forests are currently managed just to protect the environmental services provided by the soils.

EU policy on the production of bioenergy is governed by three objectives: sustainability, competitiveness, and security of supply (Schlegel and Kaphengst 2007). International standards and certification systems have been developed throughout Europe to address sustainability issues. Many groups have convened to focus on the topic, including the Roundtable on Sustainable Biofuels, the Global Bioenergy Partnership, UNEP, the

Wood Bioenergy and Other Forest Ecosystem Services

In contrast to biofuel sources such as corn, sugarcane, switchgrass and other agricultural crops, wood can be used to produce energy in a variety of ways. These include electricity production and direct burning for heat, as well as biofuel production. The primary focus of this report is on the use of wood as a biofuel feedstock. However, sustainable management of wood bioenergy requires careful attention to the balance among these multiple uses, as well as other wood products such as paper and construction materials. Further, forests provide many critical ecosystem services, for example water purification, wildlife habitat, and recreational opportunities that depend on sound sustainable management. As the Environmental and Energy Study Institute has noted, "[I]f developed carefully, this [wood] resource can contribute substantially to the renewable energy portfolio in the United States, aid in the efforts to halt global climate change, revitalize rural economies, and, most importantly, provide a valuable tool for sustainable, science-based stewardship of our diverse forests and woodlands for a full range of environmental and social values. However, if developed incorrectly, there is a risk that expanded markets for woody biomass will encourage overharvesting and other bad management practices, leading to nutrient depletion, soil damage, and loss of biodiversity and forest complexity" (Caputo 2009). Those interested in a wider discussion of wood bioenergy issues should consult the list of suggested readings at the end of this report.

International Energy Agency, and the International Bioenergy Platform. In many ways, the Nordic countries have been taking the lead by setting and amending forest policies that relate to biofuel production. They have also established several types of certification programs that could be used as models for other countries.

The Nordic Approach: Managing Forests with Bioenergy in Mind

Although the US has only recently begun to consider woody biomass in the production of fuel, researchers and policymakers in the Nordic areas of the EU have been focused on woody biomass as a source of fuel for more than 30 years. This is mostly due to the fact that countries such as Denmark, Norway, Sweden, and Finland do not have large supplies of native fossil fuels within their borders. (It is important to note that Norway remains an oil producer, with 51 active oil and gas fields on the Norwegian continental shelf. See: http://www.norway.org/business/businessnews/oilproduction.htm) When the price of such fuels rose in the 1970s, leaders in these countries were forced to think of their large forest stands (Fig. 4) as strategic assets and many began making substantial investments in forest bioenergy research and development at that time. Much of that research and development continues today.

In the last five years, there has been a rapid increase in the demand for bioenergy worldwide. Simultaneously, many have recognized a need to address potential conflicts which may arise as a result. It will no doubt become harder and harder to balance the other various ecosystem services provided by forests and crop lands against the desire to create more fuel.

In response, the EU Commission proposed the establishment of a Directive to promote the use of renewable energy while establishing biomass fuel and feedstock sustainability guidelines. This directive, which was passed by the EU Commission in December 2008 and published in the European Union Journal in May 2009,

Areas of Forestland in the Nordic Countries

Country	Millions of hectares (acres)	% of total land area
Sweden	22.6 (55.8)	55
Finland	20.1 (49.7)	78
Norway	7.5 (18.5)	23
Denmark	0.48 (1.19)	11

Figure 4. *Source: Scandinavian Journal of Forest Research, 2004, cited at http://noltfox.metla.fi/nordic.htm, viewed 8 January 2010.*

requires sustainable plans and guidelines for energy uses of biomass to be implemented by the end of 2010. The directive sets out sustainability criteria for biofuels production and use.

Although most of the Nordic feedstocks to date have been derived from residues and waste left over from the processing of other forest products, sustainability continues to be a concern as the interest in biofuels rises. Observers of the market have voiced concerns including the need to avoid or mitigate negative impacts on long-term site productivity, wildlife habitat, site quality, soil physical and chemical quality, erosion, forest health, and other ecosystem values and services.

As with other regions with large forestry sectors, the Nordic countries long ago established codes of practice in order to ensure a sustainable future. But because these countries have been working on forest produced bioenergy for three decades, and because the environmental protection programs in these countries are of very high quality, a review of their practices and codes provides some insights and lessons that could be applied to the new bioenergy ventures which are currently under development in the US today.

A Review of the Nordic Forestry Codes and Certification Programs

Denmark's focus on sustainable forestry dates back to the early nineteenth century, when the Forest Reserve Act of 1805 declared that all forests in existence must remain as forests. Over time, the Act was revised to encourage forest owners to reforest after harvesting and to maintain the quality of their sites. In the last 20 years, new legislation has aimed to conserve biodiversity in this country's natural forests and in other forest types which have high conservation value. The Nature Protection Act of 1992 provided a regulatory framework aimed at such biodiversity conservation, and the Danish Forest Act of 2004 also included provisions for ensuring the sustainability of Denmark's forests. About 20% of the country's forests are now reserved and under protection.

In addition, Denmark participates in the international Program for the Endorsement of Forest Certification (PEFC 2008). Founded in 1999, the PEFC is an independent, non-profit non-government organization that promotes sustainable forest management through independent third party certification. Certification can be used to encourage sustainable purchasing decisions. Participating countries develop their own criteria for sustainable management, including environmental, biological and ecological criteria, social criteria, and economic criteria. Only about 2% of the country's forests have been certified to date, but as biomass removal intensifies, this certification will probably become increasingly important.

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Figure 5. Map of the Nordic countries in northern Europe.

Like Denmark, **Finland's** forest protection legislation has a long and storied history, beginning with the country's Forest Act of 1886, which worked to prohibit the destruction of the country's forests. Sustainability did not become a part of the laws until much later. Although initial work towards sustainable practices was defined only under the terms of timber production, the Forest Act of 1997 emphasized that ecological and social sustainability was just as important as the economic viability already recognized in earlier laws.

Several other key pieces of Finnish legislation in the 1990s addressed forest sustainability. Some ensured compliance with the Helsinki Process and then later the Kyoto Protocol. Others addressed the need to decrease forest management costs, increase the multiple uses of forests and protect the forestlandscapes as a value asset of Finland. Interestingly, the Constitution of Finland also acts as an important piece of legislated sustainability, because it delegates the responsibility for nature, biodiversity, and the environment to all of the country's citizens. Because of this constitutional wording, all forest legislation is applicable to all forest owners and managers. Those who do not comply are subject to penalties; the government encourages compliance through guidance and advice, and the National Forestry Programmes. Finland is also involved in the PEFC certification program mentioned above.

Norway, like Finland, has many regulations that govern forest sustainability. The Norwegian Forest Act of 1965, as amended relating to forestry and forest protection, was written to promote forest production, the planting of new forests, and forest protection. Although the original act did place an emphasis on important forest values such as recreation, natural scenery, environments for plants and animals, and areas for hunting and fishing, there has been a recent push to make biodiversity a larger part of the law through revisions. Many in the country would like economic and ecological values to carry equal weight in forestry policymaking, as they do in Finland and Sweden.

The forest sector of the country is also governed by the Nature Conservation Act of 1970, which was amended in 1995. This law is aimed at halting the declines of diversity in habitats, landscapes and species. Norway also participates significantly in the PEFC.

In **Sweden**, forest bioenergy accounts for 19% of the country's total energy supply, and biodiversity protection is a key aspect of the laws governing forestry. The Forestry Act of 1994 established two equal policy goals related to sustainability: environmental protection and wood production. As a result, large reserves of forest are protected in the northern part of the country, and regulations govern operations in the rest of Sweden. Amendments made to the Forestry Act in 2005 by the Swedish Forestry Agency included a set of objectives for the nation's forest sector which include thirteen interim quantitative targets (see inset).

Sweden's Forestry Stewardship Council (SFSC), which is affiliated with the international Forest Stewardship Council, promotes environmentally sound and appropriate, socially beneficial, and economically sustainable forest management. An astounding one third of the country's forests were certified under the program by the end of 2001. Some forest owners also elected to be certified under the Swedish Forest Certification Scheme, which belongs to the PEFC.

Interim Quantitative Targets for Swedish Forest Policy (2005)

Natural productivity of forest soils. Comprehensive guidelines for preservation of natural productivity of forest soils are to be available by 2010.

Regeneration. The proportion of substandard regeneration will be reduced by half during the period 2004 – 2010, compared to 1999 – 2001. By 2010, at least 90% of naturally regenerated areas will be at suitable sites, have a sufficient number of seed trees, and receive sufficient soil treatment.

Pre-commercial thinning. The area in acute need of pre-commercial thinning will be less than 700,000 hectares by 2010.

Forest/game balance. By 2010, the proportion of young pine forest heavily damaged by elk browsing will be no larger than in the early 1990s, and wild animal browsing will not impede regeneration of mountain ash, sallow, and aspen within their natural boundaries.

Long-term protection of forestland. A further 900,000 hectares of high conservation value forestland will be excluded from production by 2010. Key woodland habitats will be preserved within that area.

Dead wood. By 2010, the volume of hard dead wood should increase by at least 40% in Sweden as a whole, and considerably more in areas where biological diversity is especially at risk.

Old forest, mature forest with a large deciduous component, and regeneration of broad-leaved forest. By 2010, the total area of mature forest with a large deciduous component will increase by at least 10%, the total area of old forest will increase by at least 5%, and the total area of regenerated with broad-leaved forest should increase.

Conservation value of final fellings (volume of trees cut). From 2004 - 2010:

- The proportion (by area) of final fellings of substandard conservation value should be reduced by half, compared with 1999 - 2001.
- On at least 50% of the total area of final fellings, conservation value should conform with the standards set by Swedish forest authorities.
- In areas of demanding biotopes, protective zones and damage to soil and water, the proportion (by area) of final fellings with very low conservation value, should be reduced by half compared with 1999 - 2001.

Balance of soil and water. By 2010, the total area being treated with fire ash will be at least as large as the area from which harvesting residues are collected in connection with final fellings.

Forest roads on wetlands. By 2004, forest roads will not be built over wetlands with significant natural or cultural assets and will not adversely affect such wetlands in other respects.

Forestry and reindeer herding. Within the limits of Sweden's Saami villages that have a formal grazing plan, forestry management shall be required to take such plans into special consideration. [The Saami are indigenous people of northern Europe who inhabit an area which encompasses parts of northern Sweden as well as Norway, Finland, and the Kola Peninsula of Russia.] By 2010, soil treatment necessary for forest regeneration within reindeer-herding areas should be carried out with minimal impact on lichen soils, soils rich in lichen, and dry soils [mainly with the plant genera *Vaccinium* and *Empetrum* growing on them] with a lichen component.

Ancient monuments and valuable historical remains. By 2010, forestland shall be managed to avoid damage to ancient monuments and to ensure that damage to other known, valuable, historical remains is negligible.

Recreational management of urban forests. By 2010, the Swedish Forest Agency shall have signed cooperative agreements with 80% of municipalities that have at least one population center of 10,000 or more. The agreement should express the entire community's long-term ambitions regarding utilization of urban forests to improve satisfaction with the supply of recreation areas. No later than 2008, the forest sector was to have conducted a national program of education regarding special consideration for the social values of urban forests. The program was intended to be directed to forest owners in urban areas and to relevant forest professionals.

Targets not set. Several important target areas were identified for which it was not possible to set interim targets. These were potential harvest levels, habitats requiring management, and ancient forests.

SOURCE: Quantitative targets of Swedish forest policy, Swedish Forest Agency, 2005. 18 p. http://www.svo.se/epierver4/dokument/sks/engelska/Quantitative....pdf

Specific Bioenergy Guidelines in the Nordic Countries

Sustainable bioenergy systems address efficiency throughout the entire life cycle, and are resource and energy efficient while having a very high potential to mitigate climate change.

Some of the important features of forest bioenergy systems highlighted by the Nordic Council of Ministers (2008) are:

- Resource efficiency, meaning high biomass production per hectare, high residues and by-products utilization, minimum waste production, and

efficient nutrient recycling;
- Energy efficiency, meaning minimal losses throughout the complete production lifecycle with low energy input relative to output, and
- Climate mitigation efficiency, meaning that greenhouse gas emissions from production are low and that the potential replacement of emissions from fossil fuels is high.

The general objectives of sustainable forest bioenergy systems are listed in Figure 6.

Specific objectives have been formulated for biodiversity and landscape aspects, water resources, soils, and social aspects. Additional guidelines have been stipulated for short-rotation forestry (SRF) used for bioenergy feedstock production due to similarities with production agriculture. These guidelines are aimed at maintaining landscape diversity and include buffer zones around SRF stands, staggered plantings to promote age and structure diversity, incorporating native tree patches within SRF stands, optimizing nutrient management, restricting chemical use to maintain water quality, and minimizing soil disturbance.

Although the US biofuel industry is rapidly expanding, the forest biofuel sector is still relatively new in comparison to Nordic countries in the EU, where the intense production of forest bioenergy has been a reality for more than 30 years.

Nordic Countries Sustainable Forest Biomass Production Practice Objectives

1 Produce low greenhouse gas emissions

2 Maintain or enhance biodiversity at a landscape level

3 Maintain ecological process and functions

4 Maintain vitality, productivity and regeneration capacity of production systems

5 Preserve and protect areas with high nature conservation values

6 Preserve cultural remains and heritages

7 Restrict the consumption of finite resources such as oil, coal and minerals

8 Minimize waste by promoting a circular flow of resources (e.g. recycling of nutrients)

9 Contribute to an increase in rural activity, economic development and energy security

10 Promote opportunities for people to experience a diverse nature and for recreation

Figure 6. *Adapted from Nordic Council of Ministers 2008.*

Certification Programs

Some certification programs are already in place in the US. The two main forest certification programs in place in the US are the Sustainable Forestry Initiative (SFI), which currently certifies about 65 million ha (160 million acres) in the US, and the Forest Stewardship Council (FSC) which certifies about 12.4 million ha (30 million acres) in the US. Over the last several years, the US Forest Service has been evaluating the various implications if it were to seek SFI and FSC certification for the 78 million ha (193 million acres) it manages.

Conclusions

As this work continues, a key to meeting the challenge of future fuel production will demand an integrated research program that synthesizes existing information on the topic while developing sustainable options and strategies for the future. These will need to include systems and practices for energy production and goods and services. Areas for additional research may include:

- Developing sustainable management and utilization systems for forest biomass and residues, forest health and fuels reduction treatments, and production forests;
- Developing and demonstrating the science and technology for sustainable, economical woody cropping systems at multiple operational scales;
- Developing sustainable management and land use systems for specific functions;
- Developing more efficient, light-on-the-land harvest, collection, and transportation systems;
- Developing highly productive feedstocks with improved water- and nutrient-use efficiencies;
- Developing efficient technologies for wood conversion to biofuels and bioproducts, and
- Refining cost and equipment information for field processing to improve efficiency and to mitigate impacts.

Suggestions for Further Reading

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